Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

UNDERGROUND ICE IN NORTHERN ALASKA*

BY

V. STEFÁNSSON

Three boat journeys of some 150 miles each through the delta of the Mackenzie River have shown no case of ice outcropping in the cut banks of the alluvial islands; neither have various winter trips through the same territory and eastward to Cape Brown revealed the presence of underground ice. That it does not occur in any of the exposed banks cannot be safely inferred, however, for it is often inconvenient to follow the land closely when travelling by sea or along wide rivers. Snow or talus may cover one month what would be visible the next. West of Herschel Island, underground ice is more frequently seen and the most casual observer can hardly avoid noticing the frequent and conspicuous outcroppings along the mainland coast and island chains from Flaxman Island west to Wainwright Inlet, the western limit of the writer's observations.

Everywhere along this stretch, perpetual frost is near the surface of the ground even in late summer. The distance down to it, at the end of August, varies (where the sun has free access) from 4 inches on level, damp, moss-covered flats to 2½ or 3 feet on sandbars that are dry and favorably located. Most years, the deepest snowdrifts on the north side of sloping hills will disappear completely, but some remnants of the larger ones persist, as many did the past summer (1908). In deep ravines, snow or ice frequently last through from year to year, even near sea level, though according to the Eskimo, an exceptionally rainy summer occasionally carries off drifts that have lain for five or more years.

The appearance of the outcropping ice is various, whether it occur along the seashore or in river banks, but in 3 things it seems to agree: there are no large, continuous ice sheets; the ice probably nowhere attains a great thickness; the earth on top of the ice is seldom if ever thick. The greatest thickness observed is less than 8 feet, while the average thickness of the surface layer is not over 2½ feet.

A sled trip in late September and early October, 1908, from the bottom of Smith Bay to Flaxman Island gave opportunity for observing ice outcroppings along the arctic shore. Probably half of this coastline consists of vertical banks which the sea is, in many places, rapidly undercutting and wearing away and these we had to follow closely, as the sea ice was not yet strong enough to allow our cutting across the small bays. There were 3 or 4 inches of snow on the ground and it was nowhere banked against the land so as to hide the face of the cliff from view.*

---

* The observations that are the basis of this paper were made, at various times, between July, 1906, and February, 1909.

In many places one may follow a cut bank for miles without seeing underground ice and then come upon it without warning given by a change in the height of the bank, character of the earth, or the trend or appearance of the coastline. There may be one, two or a few pieces of ice exposed in cross section, or much of it may extend for rods and miles; sometimes the ice is high enough in the bank to have its base exposed; sometimes the ice face extends down beneath the beach or water line. Sometimes the ice is so nearly continuous and so nearly of even height in the bank that it seems not impossible that the breaks in it may have been produced by rivulet erosion. But if that be the case, the rivulets have been so completely filled with earth that there is now no trace of them in a uniform cut bank.

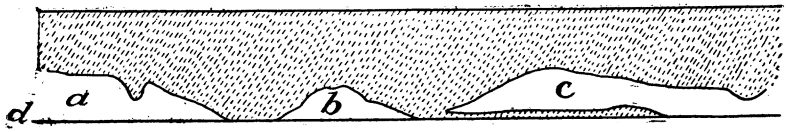

FIG. 1—*a*, *b*, *c*, ice outcropping from an alluvial bank, about 8 feet high, near Cape Halkett. Base of *a* and *b* not visible. *d*, water level; no beach.

What comes as near, as anything I know, to being a continuous ice sheet,† 4 or 5 miles in extent, is found running north along the beach from Wainwright Inlet. Unfortunately, my own observations here are of little value as I have visited the locality only in midwinter. I must depend, for a description, upon the U. S. Government teacher at this place, Mr. J. E. Sinclair. Ice is also exposed near the Government coal mine on the Inlet itself, some six miles away; of this I present a diagram drawn by Mr. Sinclair.

Along the sea beach the ice is exposed so continuously that it had impressed Mr. Sinclair as a continuous sheet, cut here and there by small ravines, and covered in many places by talus. Where the base of the ice was exposed its thickness was nowhere over 9 feet, while at others it was only 3 feet.

---

* The cut bank varies in height from 5 to perhaps 20 feet. The highest are those east of Smith Bay.

† See discussion further on of ice house dug into this "sheet" of ice.

In three localities, known to the writer, deep artificial excavations have been made into or through underground ice—at Flaxman Island, Point Barrow and Wainwright Inlet.

At Flaxman Island an ice house, for cold storage of food was dug on level tundra. The island is low and fairly level, probably nowhere rising much over 20 feet above the sea; perhaps a fifth or sixth of its surface is now covered with fresh water ponds. Small stones and some good-sized boulders are found on the surface, sometimes directly above beach outcrops of underground ice.

The excavation of the ice house was first through over 2 feet of soil and then through 6 feet of ice. This ice had grains of sand in it and fragments of rock, some rather larger than a coffee bean. Below the ice the excavation was continued a foot or two into earth of a similar character to that above the ice.*

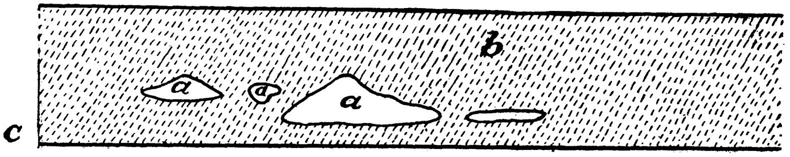

Fig. 2—Section of a cut bank, 12-15 feet high. Bank (*b*) composed of peat mixed with earth. *a*, *a*, *a*, ice apparently free from earthy impurities. Largest piece has a horizontal exposure of 12 feet and a vertical height of 5 feet.

At Cape Smythe, near Point Barrow, where an ice house was dug, the excavation was some 10 feet deep and was through earth except in one corner where a block of ice was so situated that rather less than one-fourth of the ice house is dug in ice.

The general character of the other ice houses at Cape Smythe is similar to that just mentioned, though some of the excavations answer fairly well the below detailed description of the Government ice house at Wainwright. Others, dug near ice houses in ice, show no sign of anything but sand or gravel. The deepest excavation is that dug by Lieut. Ray's expedition to a depth of over thirty feet. In the walls of this no signs of ice are found. An interesting feature of this shaft is that 3 feet of salt water stood unfrozen in its bottom for years, while six feet above, the cold was intense enough to keep deer meat continually frozen summer after summer. This shaft is about 100 yards from the ocean beach, while the surface of the water in the bottom of it seems to be a little below the level of low tide. The gradual drying of the walls and the resulting crumbling of the sand have filled the bottom of the shaft.

---

* This description is admittedly loose. It is taken from a verbal account by one of the workmen who dug the ice house.

The general surface characters of the land around Cape Smythe are much the same as those of Flaxman Island—level land only a few feet above sea level.

Near the U. S. Government school, two miles north of Wainwright Inlet, an ice house was dug through about 3 feet of earth and 7 or 8 feet into the ice. A hole three feet deep at the bottom of this ice house failed to penetrate the ice, so this gives a thickness of something over 11 feet—the greatest ascertained thickness known to the writer.

The appearance of the walls of this ice house is characteristic and, in my belief, typical of much of the ice that outcrops upon the seashore. It should be solid ice, and ice of one kind generally, if it had been formed and frozen in its present position, but the fact is that it presents the appearance of a heap of fragments and blocks, of varying size pressed together. Neither are these fragments similar. They differ in some being "clean" ice and some "dirty;" they differ in color where they are apparently formed out of clean (not muddy) water; some are transparent, others milky; some of the dirty ice is discolored by foreign materials (muddy water ice), while some has clear layers alternating with discolored layers in a sort of stratification. Even these last may be re-classified into two groups—those which have their dark bands composed of "muddy water ice" and those in which the dark bands are not ice at all but earth—sometimes sand, sometimes peat.

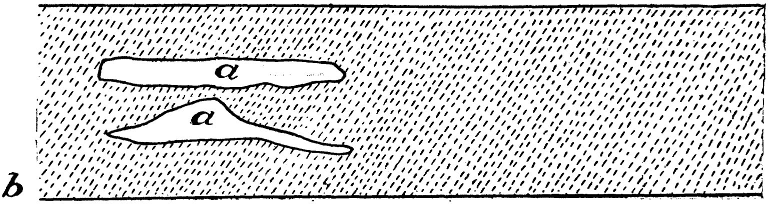

FIG. 3—Ice outcropping in alluvial cut bank near Pitt Point. *a*, *a*, ice worn level with face of bank. Upper piece about 15 feet long and 20–24 inches thick. *b* is beach level.

Even a rough sketch of one of the walls of the Wainwright ice house gives a better idea of the character of the ice than would much description. In some places, it seems as if smaller pieces of ice had been fused into larger ones by thawing, pressure and re-freezing. Some pieces seem to have been thin and to have been crumpled (not crushed) by lateral pressure so that their position in the ice wall is now indicated by wavy lines. And between and among all these heterogeneous ice blocks are fragments, layers and huge masses of earth. Here and there, also, are corners and crevices packed solid with snow, not large quantities, but a thimbleful here and a handful there. In some places this snow has been pressed and water-soaked so that it differs little from the rest of the wall in hardness; in others it is so soft as to be easily scratched with the fingernail.

Some of the thinner layers of earth in the wall of this ice house are sand and others peat, but the larger masses are entirely of fine sand. While some of these look as if they might have been in their present form at the time the ice was heaped up around them, others suggest that thin mud flowed into empty spaces, between loosely piled ice blocks, and froze there.

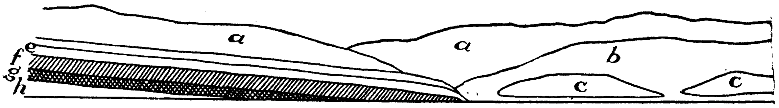

Fig. 4—Ice and coal outcropping at Government coal mine, Wainwright Inlet. *a*, *a*, hill slopes covered with grass and moss. *b*, clay and gravel talus. *c*, *c*, ice about 8 feet thick. *e*, blue clay. *f*, lignite, 4½ feet. *g*, sub-bituminous coal, 2½ feet. *h*, high water mark. The ice extends below the level of the beach.

In several places, the ice house walls show frost cracks such as are found everywhere in frozen ground, but these are easily distinguished from the typical thin mud layers in the ice wall by the fact that the frost cracks are straight or harshly angular, in distinction to the flowing curves of the others, which suggest that they were formed by wind or water action.

The ice houses of Eskimos living at Wainwright show, in general, characters similar to those found in the Government ice house. One of them, though larger than the Government ice-house, shows no large masses of earth in the walls or floor, though the thin mud layers streak the walls here and there. In one corner, however, a significant thing is observable—an open space where none of four ice blocks had touched each other but had left a small pyramid-shaped chamber to which neither water, snow or sand had found access, evidence, apparently, that the pressure under which the ice was heaped was not strong enough to close all crevices.

It remains to outline four different processes by which the writer has seen underground ice formed. That there are other methods by which it is formed in this locality seems probable; that remote localities and remote times may have had others seems still more likely.

FORMATION OF UNDERGROUND ICE ALONG THE SEASHORE THROUGH WIND PRESSURE. Along a gravel beach running from Cape Smythe towards Point Barrow there were, in the summer of 1908, a number of mounds, the largest rising 12 or 15 feet above their base level and with a basal circumference of say 50 feet. Some were a considerable distance apart, others touched each other and formed a sort of double or treble mound. Scratching into these heaps with a stick showed that the main body of them was ice, with a covering of gravel. Tongues of ice had been thrust into the land. When the tide fell and the water retreated the main body of the ice broke away, leaving pieces, weighing tens of tons, in some cases, imbedded in the ground. It is probable, because of the thinness and porosity

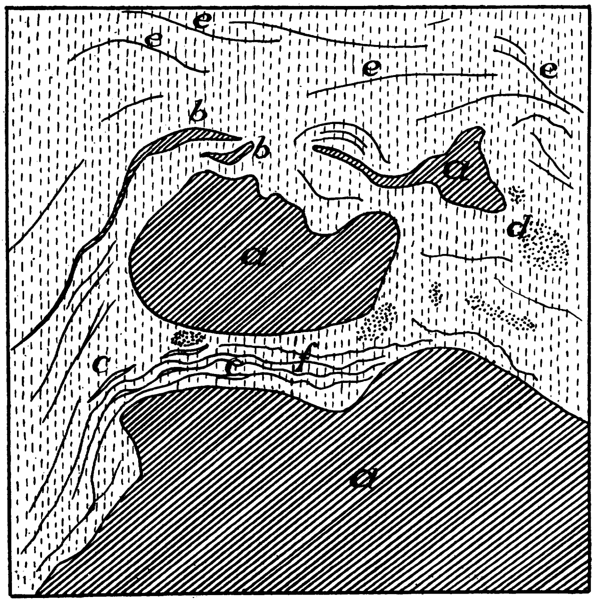

FIG. 5—Sketch of part of east wall (6 ft. by 6 ft.) of Government ice house, Wainwright. The vertical broken lines represent ice. *a*, *a*, *a*, masses of earth. *b*, *b*, sand with laminæ of ice between. *c*, *c*, pockets of sand. *d*, masses of snow, here and there, more or less compressed and some solidified into ice. *e*, thin layers of sand or peat. The ice at *f* seems to have been subjected to strong lateral pressure, hence the wavy lines.

of the gravel and the consequent penetration through it of every summer shower, that even the largest of these ice blocks will disappear in a few years and the beach resume approximately its former appearance.*

A gravel and ice hill similar to those just described is situated on the north coast about half way from Smith Bay to Cape Halkett. This hill, an Eskimo told me, was there six years ago and has not decreased noticeably in size. At the eastern entrance to Smith Bay are two similar heaps, but covered with peat instead of gravel. That their core is ice is merely inferential, for their outside was frozen hard. In my observation, 5 or 6 inches of wet peat will keep ice from melting through an ordinary summer. A foot or 14 inches of damp mud would serve the same purpose, though dry sand thaws down deeper. A typical ice block shoved in, as described above, would carry in with it not only dry snow but snow soaked with sea spray and frozen, while in the very centre of a cake might be found

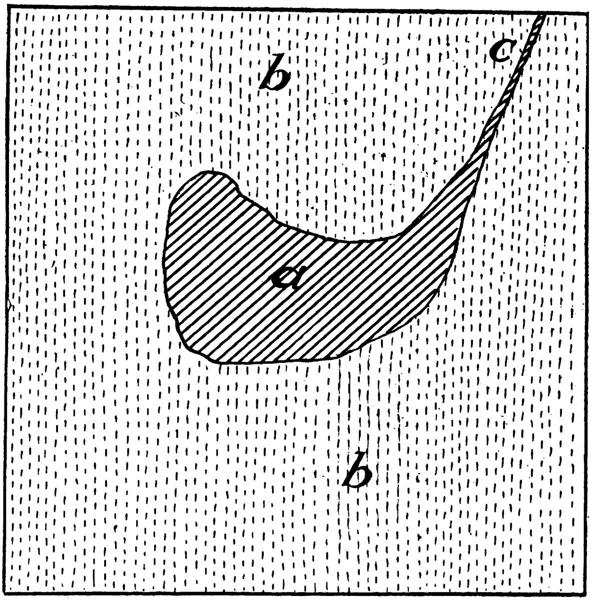

FIG. 6—Part of west wall of Government ice house at Wainwright. *a*, mass of mud that seems to have flowed into a cavity in the ice and frozen there. *b*, *b*, clear ice. *c*, crack through which mud flowed in?

---

* Some, apparently, persisted in former times, however, for the ice-house dug in the spring of 1908, of the Cape Smythe Whaling and Trading Co. was excavated through gravel mixed with boulders of ice evidently formed in muddy water, such as is formed in autumn along the beach when a southwest gale heaps muddy slush-ice in the shore water.

snow similarly frozen by a submergence, by pressure, of the ice cake while it was out at sea.

PRESERVATION OF SEA ICE UNDER MUD DEPOSITED BY RIVERS. At the mouths of most arctic rivers, the sea is so shoal that it freezes to the bottom for a greater or less distance from shore. Sometimes the river, especially if one of considerable size, has an open channel to deep water somewhere all winter, but that does not alter the fact of there being much bottom-frozen ice near the river mouth. If the entire stream freezes to bottom we have winter overflows and water (muddy or clear) may flow at any time out over the older ice, so that the ice of a river, in cross section, shows, by spring, many layers of ice, now of muddier water, now of clearer, with more or less of snow-ice between. But whether this flooding happens or not, one overflow is certain, that of the spring break-up when the muddy river spreads for miles over the sea-ice near its delta. I have seen the mud layer deposited by the water, as it loses its current at the river's mouth, thick enough to preserve ice several inches thick into autumn of the following year; with favorable conditions, it seems that a thin ice layer of one year might be added to by a thin layer of the next, and thus ice deltas be formed much as mud deltas are in rivers. In certain shoal bays it seems not impossible that the muddy overwash by the sea in a storm might have a like effect.

ICE AND SNOW PRESERVED BY DRIFTING SAND. On the Jones Islands (miscalled "Thetis Islands" on some charts) just east of the Colville delta, I found, in the summer of 1907, ice and snow under a few inches of damp sand. This was late in July, but it seemed to me evident that the snow and ice had been there more than one season. When the wind blew hard, sand drifted considerably on those islands and formed small dunes in places; judging from the dirtiness of the snow, at a considerable distance from the island, this winter (1908-9), it seems that sand drifts there to some extent at all seasons, so that a snowbank might get a considerable coating before spring and a much thicker one before the summer sun had thawed even the unprotected drifts near it. The drifting of sand and dust from the mud and sand bars at the mouths of rivers upon the ice near them is also a contributing factor in furnishing a preservative coat to the ice that sometimes persists there throughout the summer.

ICE PRESERVED BY THE SHIFTING OF CHANNEL OF A MEANDERING RIVER. In the banks of the Colville, there may be found ice outcroppings, at least 25 to 40 miles from the river's mouth. This ice may have been formed and preserved as already indicated, but as ice benches along cut banks are frequently maintained late into the summer, even in locations not particularly favorable, and as sand bars are often piled up with astonishing rapidity in the arctic rivers, it seems not unlikely that one of these benches should now and then be covered with sand or mud sufficiently deep to preserve it indefinitely. Incidentally it may be suggested that the carcass of an animal (*e. g.*, a mammoth) would, in like manner, be indefinitely preserved if the beast were to die at the growing end of a sandbar in a river whose channel is shifting across a roomy floodplain.

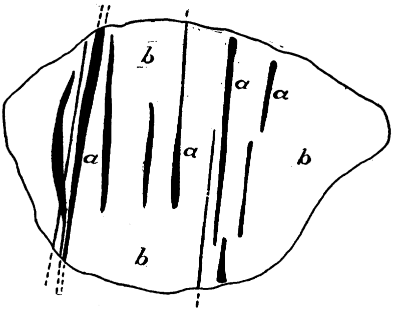

FIG. 7—A piece of ice chipped from wall of Government ice house at Wainwright. Half natural size. *a*, black earth of peat-like character. *b*, ice.

Finally, it may be noted that, both along the arctic coast and on the north flowing rivers, the comparatively warm water undercuts the vertical banks in numerous places. For this reason huge blocks tumble down every now and then. It might be supposed that these would fall down in summer invariably, on account of the undercutting at that season and the thawing of the ground. As a matter of fact, the thawing of a few inches on the surface makes little difference and the rapid undercutting may be credited with the fall of such banks as do fall. In winter, however, a sharp frost or sudden change of temperature often causes the earth to crack to a great depth.[*] If one of these cracks happens to be suitably located, it cuts off the projecting bank and it may tumble upon the ice below in mid winter. If other conditions are suitable, this huge bulk may protect the ice under it from melting, but it is of course more usual that the river or sea, the next summer, breaks up the mass and carries it away.

On Herschel Island, where, by the way, no underground ice has been found in digging numerous ice houses, and where none is known to outcrop, landslides frequently bury snowbanks and ice shelfs at the foot of a cliff, but this preserves them only a year or two, for, along the steep cliffs, the shoreline is continually receding.

---

[*] The writer has seen frost cracks in the mudflats of the Colville that are a hundred and more yards long, and wide enough so that a man occasionally stumbles by his foot slipping into them through the snow.